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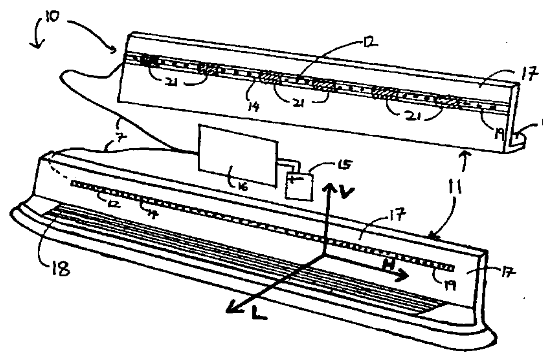
(54) SYSTEME D'ECLAIRAGE DE MARCHEPIED
(54) RUNNING BOARD LIGHTING ASSEMBLY

(57)
A running board lighting assembly consisting of an array of LEDs, a lens tube and a power circuit provides distributed light to the surface of a running board step which appears to be evenly distributed and which, when reflected from the running board step surface, appears to have a near incandescent quality. The LED array includes conventional green LEDs, which also emit longer wavelengths, horizontally and evenly spaced within the lens tube. The lens tube is installed within the running board cladding, above the running board step. The lens tube is extruded from acrylic material containing appropriate dye, so that when light from the green LED array passes through the lens tube, the green wavelengths are blocked and the yellow and some red wavelengths are passed, causing the resulting light reflected off the running board step to have a near incandescent appearance. The LEDs are interleaved in strings of four each, so if one string fails, the failure will be nearly imperceptible. The power circuit connects to the vehicle battery and regulates the current passing through the LED array. The power circuit also controls the on/off state of the running board lighting assembly according to the state of the courtesy lights and the on/off state of the vehicle's engine.



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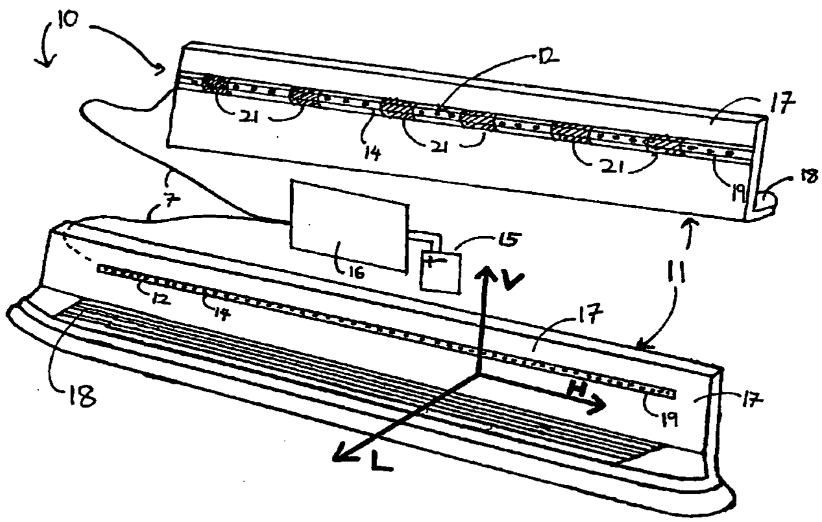
(54) SYSTEME D'ECLAIRAGE DE MARCHEPIED
(54) RUNNING BOARD LIGHTING ASSEMBLY



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ABSTRACT OF THE DISCLOSURE

A running board lighting assembly consisting of an array of LEDs, a lens tube and a power circuit provides distributed light to the surface of a running board step which appears to be evenly distributed and which, when reflected from the running board step surface, appears to have a near incandescent quality. The LED array includes conventional green LEDs, which also emit longer wavelengths, horizontally and evenly spaced within the lens tube. The lens tube is installed within the running board cladding, above the running board step. The lens tube is extruded from acrylic material containing appropriate dye, so that when light from the green LED array passes through the lens tube, the green wavelengths are blocked and the yellow and some red wavelengths are passed, causing the resulting light reflected off the running board step to have a near incandescent appearance. The LEDs are interleaved in strings of four each, so if one string fails, the failure will be nearly imperceptible. The power circuit connects to the vehicle battery and regulates the current passing through the LED array. The power circuit also controls the on/off state of the running board lighting assembly according to the state of the courtesy lights and the on/off state of the vehicle's engine.

Title: RUNNING BOARD LIGHTING ASSEMBLY

FIELD OF THE INVENTION

The present invention relates generally to lighting devices and in particular to a running board lighting assembly for illuminating the surface of a running board of an automotive vehicle.

BACKGROUND OF THE INVENTION

Vehicle running boards provide an intermediate step to aid in the entry or exit of an automotive vehicle and typically extend from the rear of the front wheel to either the end of the front doors or to the front of the rear wheel well. Lighting assemblies for illuminating vehicle running boards are associated with the running boards for both decorative and safety purposes. Running board manufacturers have made various attempts to provide safe and aesthetic lighting of the running board by attaching a number of discrete lamps either beneath, along or slightly above the running board step.

For example, running board lighting assemblies such as that disclosed in United States Patent No. 4,463,962 to Snyder utilize elongate light strips formed of a flexible polymer tube having small incandescent bulbs wired in parallel throughout the tube. Incandescent bulbs are used for their omni-directional light characteristics as well as their aesthetic lighting colour. However, the use of incandescent bulbs results in an unreliable and ineffective assembly which requires a high degree of maintenance, due to several physical shortcomings of incandescent lamps and their general incompatibility with the roadside environment. Since incandescent light bulbs provide illumination 360 degrees around the bulb a number of other undesirable effects are produced. An inconsistent quality of light and increased glare is cast upon the surface of the running board and direct light is caused to shine in the user's eyes. Also, an amount of "leakage" of light appears within the space between a running board cladding and the vehicle shell causing an unaesthetic effect.

Incandescent bulbs have a resistive tungsten filament suspended by support wires with a vacuum inside a glass envelope. As a result, they are highly susceptible to damage due to variations in temperature, mechanical shock or vibration and voltage spikes or transients. Since running board lighting devices are generally positioned at the bottom of a vehicle, severe environmental and/or mechanical shocks and bumps may be endured when the vehicle traverses rough roadside terrain. Under such conditions additional forces and stresses are exerted on the entire running board lighting assembly and incandescent bulbs can be easily damaged.

Attempts have been made to reduce the amount of multidirectional glare emitted by standard running board lighting assemblies, such as in United States Patent No. 5,915,830 to Dickson et al. where a light source is used to emit light into one end of a light tube extending along the length of a running board. However, in practise, it has been observed that the light emitted by each light source significantly attenuates after approximately 60 to 70 centimeters within the light tube. This effect results in the production of an inconsistent quality and aesthetically displeasing quality of light within the tube.

Thus, there is a need for a running board lighting assembly which can provide uniformly distributed light along the length of the surface of a running board step such that near incandescent quality light is reflected from the running board step, which can withstand substantial environmental and operational stresses associated with roadside application, which can operate for a long period of time without replacement, which requires minimal maintenance, and which can be manufactured easily and inexpensively.

BRIEF SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide a running board lighting assembly for the illumination of the surface of a running board step of a vehicle, said running board lighting device

comprising:

(a) a plurality of LEDs spaced apart from each other and extending horizontally above the surface of the running board step;

(b) a light transmitting member encasing the LEDs; and

(c) a power circuit for supplying electrical power to the LEDs.

Further objects and advantages of the invention will appear from the following description, taken together with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings:

Fig. 1 is a diagrammatic view of a preferred embodiment of a running board lighting assembly according to the invention installed with a running board assembly;

Fig. 2A is a front view of either LED array of Fig. 1;

Fig. 2B is a graph illustrating the directional luminous intensity pattern of the preferred LED type for the LED array of Fig. 2A;

Fig. 3 is a cross-sectional view of either lens tube of Fig. 1;

Fig. 4A is a side elevational view of one of the LED array and lens tube assemblies of Fig. 1 showing the lateral (L) lighting characteristics of the assembly;

Fig. 4B is a graphical representation of the relative illuminance of the LED array and lens tube assembly of Fig. 4A taken along the line A-A′ of Fig. 4A;

Fig. 4C is a graphical representation of the relative illuminance of three LEDs of LED array spaced apart more than 12 millimetres through lens tube and taken along the line B-B′ of Fig. 4A;

Fig. 5 is a front view of one of the LED array and lens tube assemblies of Fig. 1 showing the horizontal (H) lighting characteristics of four LEDs spaced at least as close as 12 millimetres apart;

Fig. 6A is a comparative graph illustrating the irradiance versus wavelength characteristic of one preferred LED type for the LED array shown in Fig. 1 in comparison with that produced when filtered through the lens tube of Fig. 1 and that of a standard yellow LED source;

Fig. 6B is a standard chromaticity graph for an observer having a two degree viewing angle illustrating the relationship between the perceived colour of the light assembly of Fig. 1 at A and the perceived colour of the inside courtesy lights of the subject vehicle at B;

Fig. 7 is a graph illustrating the transmission ratio versus the wavelength for either lens tube of Fig. 1;

Fig. 8 is a schematic diagram of either LED array of Fig. 1;

Fig. 9 is a diagrammatic view of either LED array of Fig. 1 mounted on the printed circuit board of the power circuit of Fig. 1;

Fig. 10 is a block diagram of the power circuit of Fig. 1; and

Figs. 11A, 11B, and 11C are cross-sectional views of either lens tube of Fig. 1 showing how the design of the retaining channel of lens in association with the flexible printed circuit board provides for additional durability of the lighting assembly of Fig. 1.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Reference is first made to Fig. 1 which shows a running board lighting assembly 10 made in accordance with a preferred embodiment of the present invention and installed within a conventional running board assembly 11. Lighting assembly 10 comprises a pair of light emitting diode (LED) arrays 12, a pair of lens tubes 14, and a power circuit 16. Lighting assembly 10 is designed to provide uniformly distributed light on the surfaces of running board steps 18 such that near incandescent quality light is reflected from running board steps 18, as will be further described.

While lighting assembly 10 includes a pair of LED array 12 and lens tube 14 assemblies, each of which are to be installed within an appropriate section of cladding 17 of running board assembly 11, the following description will generally refer to one singular LED array 12 and

lens tube 14 assembly as installed within one section of cladding 17 in respect of one running board step 18, for purposes of clarity.

Solid state LEDs are semiconductor devices that convert electrical energy directly into light, and are relatively immune to electrical and mechanical shock, vibration, frequent switching and environmental extremes. In contrast, standard bulb type lamps are not immune to failure conditions such as filament breakage due to sudden shocks or bumps and are ill suited for use in the turbulent and extreme weather conditions of a typical roadside environment.

Accordingly, LEDs are a particularly desirable lighting source to use in association with running board assembly 11 which typically will encounter hostile environmental conditions and high impact vibrations and shocks during use. Additionally, LEDs are highly energy efficient and produce relatively high illumination using relatively little electrical power. For example, a typical incandescent lamp operates on 5 volts and uses a current of 115 milliamps while a LED can operate on less than 3 volts and draw current on the order of 1 to 20 milliamps. This ensures that relatively low amounts of power are drained from the vehicle's battery 15.

The LEDs of LED array 12 are preferably green LEDs such as the ROHM™ SML-010 series ML green LED manufactured by Rohm Co., Ltd., of Japan. Since the average rated lifetime of LEDs is approximately 1,000,000-plus hours (or 11 years), LED array 12 provides lighting assembly 10 with an extremely energy efficient, long lasting and durable light source. Further, this type of LED is relatively inexpensive (e.g. 4 to 6 cents ($Cdn) each), in comparison to other green LEDs and even more so in comparison to white or blue LEDs (e.g. 50 cents each).

The LEDs of LED array 12 are installed in cladding 17 which is positioned approximately 6 to 7 centimeters vertically (V) above the surface of running board step 18 (V, H, and L define vertical, horizontal and lateral directions). The LEDs of LED array 12 are spaced apart evenly in a line which is oriented parallel to the horizontal axis (H) of running board step 18. LED array 12 illuminates the surface of running board step 18

evenly in the horizontal (H) and lateral (L) directions, as will be described in detail.

Lens tube 14 houses LED array 12 and extends in the horizontal (H) direction of running board step 18. Lens tube 14 is preferably manufactured from a suitable transparent synthetic plastics material which has a high resistance to mechanical damage such as scratching, and to degradation due to exposure to ultraviolet light (e.g. ACRYLIC™). Lens tube 14 can be conveniently and inexpensively manufactured by conventionally known extrusion methods. Lens tube 14 can be secured within conventional cladding 17 by sliding lens tube 14 within a channel defined by a plurality of support tabs 21 which are formed on the back side of cladding 17. Once lens tube 14 is fully installed within cladding 17, only a longitudinal portion of the surface area of lens tube 14 is exposed through the slot opening 19 formed within cladding 17.

Power circuit 16 is coupled to the automotive vehicle's battery 15 (which typically provides approximately 12 volts) through lamp wires 7 and provides regulated DC power to LED array 12 through a printed circuit board 23 (Fig. 2A) which is also housed within lens tube 14. Power circuit 16 powers, and regulates the amount of current provided to, LED array 12 such that each LED receives approximately 20 milliamps of current. The operating conditions provided by power circuit 16 allow the LEDs of LED array 12 to produce sufficient illumination to properly illuminate the surface of running board step 18 through lens tube 14, as will be described. Power circuit 16 uses a programmable logic circuit to integrate light assembly 10 into a vehicle's lighting system as well as to turn lighting assembly 10 on and off in accordance with state and provincial transportation lighting protocols which regulate the use of external lights on automotive vehicles.

Now referring to Fig. 2A, a complete string of 128 Rohm™ brand LEDs of LED array 12, or specifically, LEDs, LED_1, LED_2 to LED_{128} are shown. These LEDs are high luminance chip LEDs with built in reflectors and are suitable for automatic mounting. While a single type of LED is

preferred, it should be understood that other types of LEDs may be used within LED array 12 to effect various aesthetic lighting patterns (e.g. the use of different coloured LEDs at the ends or within LED array to provide fanciful colour designs).

It has been determined for optimal aesthetic and cost reasons that for an illuminated length of approximately 1.5 meters, it is necessary to position the LEDs of LED array 12 (LED array 12 being positioned 6 to 7 centimeters above the surface of running board step 18), such that each LED is spaced a distance D from its neighbouring LED of 12 millimetres (from respective center to center). This configuration requires the use of 128 individual LEDs per LED array 12. Further, it should be noted that four separate printed circuit boards 23 need to be used, each soldered to the other to produce the LED array 12 and printed circuit board 12 assembly of Fig. 2A.

Fig. 2B illustrates the directional pattern of the relative luminous intensity of each LED of LED array 12. Specifically, it can be seen that each LED has an output beam width (bounded by its one-half intensity curve 21A) of approximately 110 degrees. That is, a 50 per cent falloff in light output occurs at the edge of the 110 degree cone of light produced by each LED. As discussed below, it has been determined that by arranging LEDs, LED_1, LED_2, to LED_{128} of LED array 12 millimetres apart, an optimum trade off between the aesthetic effect of the resultant lighting effect and cost factors can be obtained.

It has been established by visual study that when the LEDs of LED array 12 are arranged 12 millimetres apart, the LEDs of LED array 12 are positioned 6 to 7 centimeters above running board step 18, and lens tube 14 is provided with a slightly milky surface, LED array 12 appears as a continuous light source within lens tube 14. This is the case even when a subject looks directly into the LEDs. When the LEDs of LED array 12 were placed at a distance larger than 12 millimetres, the presence of discrete LED light sources within lens tube 14 starts to be noticeable to an observer.

Finally, it is worthwhile noting that due to the directional

characteristics of the LED array 12, the LEDs produce negligible luminous intensity at the extent of the 180 degree output beam width. This along with the physical presence of printed circuit board 26 positioned on the back of LED array 12, prevent light "spillage" along the cladding 17 of the running board step 18, a longstanding problem in prior art incandescent running board assemblies.

Fig. 3 illustrates the cross-section of lens tube 14 which houses LED array 12 and which extends in the horizontal (H) direction of running board step 18. Lens tube 14 comprises a curved portion 20, a retaining channel 22, and a deformable portion 24 and has a smooth exterior surface 9. The smooth exterior surface 9 minimizes the collection of dirt and debris on the lens when the lens is used in association with a running board assembly 11.

Curved portion 20 extends horizontally (H) along the length of lens tube 14 and includes a plurality of rows of integral ribs 26, all the rows being mutually parallel and extending horizontally (H) along the entire length of the inside surface of lens tube 14. As discussed above, only the interior surface of curved portion 20 includes the optical details of the horizontal ribs 26. It should be understood that while it would be advantageous to have ribs 26 extending laterally (L) within curved portion 20 of lens tube 14, it is much more economical to utilize horizontally (H) extending ribs 26 which can be formed as part of the extrusion process used to manufacture lens tube 14.

The radius of curvature of curved portion 20 is approximately 4.5 millimetres. Each rib 26 comprises a triangular shaped projection 27 which extends from between two circular grooves 29 within the surface of curved portion 20. All of the triangular projections 27 are identical and all of the circular grooves 29 are identical. Specifically, the radius of curvature of each circular groove 29 is approximately .120 millimetres. The height of each projection 27 from the base of each groove 29 is approximately .212 millimetres. The horizontally (H) extending projections 27 and grooves 29 form a conventionally known diffraction pattern which serves to

distribute the light generated by LED array 12 laterally along the surface of running board step 18, as will be described.

Retaining channel 22 provides a horizontally (H) extending channel that extends along the length of lens tube 14 and which is adapted to receive printed circuit board 23 with ample remaining room within retaining channel 22 so that printed circuit board 23 may still have limited movement within retaining channel 22, as will be discussed.

Deformable portion 24 extends horizontally (H) along the extent of lens tube 14. Deformable portion 24 comprises a horizontally (H) extending attachment section 25 and a horizontally (H) extending flanged element 27 that is coupled to attachment section 25 at an angle A of approximately 63 degrees. Deformable portion 24 is designed to deform when lens tube 14 is inserted into the channel defined by support tabs 21 and located at the back of cladding 17. Specifically, attachment section 25 deforms slightly such that it is moved in the direction of retaining channel 22, and flanged element 27 deforms slightly towards attachment section 25 at a reduced angle A. In this way, lighting assembly 10 can be removably and securely installed within cladding 17 of running board assembly 11.

Figs. 4A, 4B and 4C show how light from LED array 12 is transmitted through lens tube 14 and cast onto running board step 18 in a series of uniform lateral (L) bands B along the horizontal (H) extent of running board step 18. As previously discussed, each projection 27 and groove 29 of ribs 26 extends for the complete length of lens tube 14 and forms a conventionally known diffraction lens pattern on the inside surface of lens tube 14. It should be noted that in order to adapt lighting assembly 10 to various types of running board assemblies 11, it is necessary to position lens tube 14 at different distances from the surface of running board step 18. In the following discussion, it should be assumed that lens tube 14 is positioned 6 to 7 centimeters above the surface of running board step 18.

As is also conventionally known, a lens element having a plurality of aligned rows of ribs having a part-circular cross-section

provides an effective horizontal (H) and lateral (L) distribution or even spread of light intensity below the lens element from a source placed behind the lens element. The ribs 26 of lens tube 14 have a part-circular cylindrical cross-section having a radius of curvature of approximately .120 millimetres and a part-triangular cross-section having a height of approximately .212 millimetres. It has been determined that the particular shape of projections 27 and grooves 29 succeed in efficiently redirecting light emitted from LED array 12 to achieve uniform light distribution over the surface of the running board step 18.

Specifically, lens tube 14 optimizes and redirects the non-parallel light rays which are emitted by LED array 12 by refracting portions of the light rays to various extents depending on the relative curvature and thickness of the curved portion 22 of lens tube 14 which receives each individual light ray as shown in Fig. 4A. The curvature of curved portion 20 of lens tube 14 that is provided through slot opening 19 of cladding 17 further assists to disperse the light rays downwards towards the portion of running board step 18 which runs proximate to cladding 17.

Accordingly, for each individual LED, the horizontally (H) disposed ribs 26 serve to distribute the light rays emitted from the LED so that substantially constant optical characteristics are produced for a given laterally (L) extending light band B as shown. It should be noted that lens tube 14 also provides light rays that extend past the edge of running board step 18 and onto the ground beside running board 11 (Fig. 4A). It should be noted that lighting assembly 10 can thus provide ground lighting and step lighting for addition safety.

Referring specifically to Fig. 4B, the relative illuminance cast on the surface of running board step 18 which exists along the line A-A' of Fig. 4A is shown. The illuminance is perceived to be substantially uniform along the lateral (L) extent of light band B. Without lens tube 14, the light emitted by each individual LED would be projected onto running board step 18 as an intense spot of light. By using the horizontally disposed ribs 26 of lens tube 14, it is possible to distribute the light intensity of the casted

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light evenly in the lateral (L) direction along the surface of running board step 18.

Referring specifically to Fig. 4C, the relative illuminance cast on the surface of running board step 18 which exists along the line B-B' of Fig. 4A is shown. Three individual LEDs of LED array 12, LED_1, LED_2 and LED_3, are shown spaced apart by a distance D substantially greater than 12 millimetres (e.g. 5 centimeters) at a distance of 6 to 7 centimeters above running board step 18, for illustrative purposes only. As shown, each light band BND has a specific "footprint" on the surface of running board step 18 which appears a horizontal (H) series of lighting stripes. The reduced illuminance which exists between the stripes of bands BND can create an uneven lighting pattern on running board step 18.

Fig. 5 is a graphical representation of the light intensity produced by four individual LEDs, LED_1, LED_2, LED_3 and LED_4 which are positioned along the horizontal extent (H) of running board step 18. This is the preferred configuration of the LEDs of LED array 12 of the present invention where the distance (from center to center) between LEDs is approximately 12 millimetres. As previously discussed, in order to provide even illuminance along the horizontal (H) extent of running board step 18, it is necessary to position the LEDs of LED array 12 close together so that their light bands BND intersect and re-enforce one another appropriately.

This configuration allows for slight faults and non-uniformity in brightness characteristics of individual LEDs of LED array 12. Further, since illuminance is linearly additive, the brightness of the LED array 12 will never fall below 50% of any one of its individual LEDs. In this way, a substantially uniform distribution of light will be provided horizontally (H) along running board step 18. It has been observed that where lens tube 14 is positioned closer to the surface of running board step 18 (i.e. closer than the 6 to 7 centimeters used in this illustrative example), the distance of 12 millimetres between LEDs of LED array 12 is not sufficient to disperse the light so that it does not form distinct stripes. In such a case, the LEDs of LED array 12 must be positioned closer together,

lens tube 14 must be provided with a milky white finish, and/or be provided with ribs 26 which extend in the lateral (L) direction, in order to achieve appropriate dispersement of light, for an even distribution of light on the surface of running board step 18.

Accordingly, the inventors have determined that for any particular point on the surface of running board step 18, the LEDs of lighting assembly 10 can be configured to produce a substantially uniform distribution of light intensity on the surface of running board step 18 in both the horizontal (H) and lateral (L) directions.

Further, the inventors have determined that it is possible to provide the reflection of near incandescent quality of light from the surface of running board step 18 can be achieved by using an appropriately pigmented lens tube 14 in association with the green LEDs of LED array 12. As is well known, the colour of incandescent light or what is commonly referred to as "incandescent yellow" is formally defined as having an average wavelength of 575 nanometres. By using lens tube 14 (having an appropriate light wavelength passband) as a light filter to filter the light which is emitted by the green LED array 12, light having a wavelength substantially close to 575 nanometres when reflected from running board step 18 can be produced, as will be described.

As shown in Fig. 6A, the green ROHM LEDs, preferably used in LED array 12, have a peak irradiance at a wavelength of 570 nanometres and have a wavelength distribution 100 which is not strictly monochromatic. Rather, the significant portion of the wavelength distribution (i.e. portion that has an irradiance that is greater than 1 microwatt/centimeter^2/nanometer as shown in Fig. 6A) ranges from wavelength frequencies of 550 nanometres to 600 nanometres. This largely spans the standard LED colour wavelengths, which include red (600 to 620 nanometres), amber (590 to 600 nanometres), yellow (570 to 590 nanometres) and green (560 to 570 nanometres).

By filtering out colour wavelengths associated with the green wavelengths it is possible to shift the light emitted by the LED array 12

towards the yellow section of the spectrum and approach the "incandescent yellow" for incandescent quality light. It should be noted that since running board step 18 is typically of a dark colour (e.g. black) which exhibits complex reflective behaviour under low ambient light, it is necessary to further adjust the filter characteristics to compensate for this effect.

As shown in Fig. 6B, every visible colour can be found in the standard CIE 1976 u'-v' Chromaticity Chart (for a two degree observer) and can be expressed by its u' and v' colour coordinates. Colours of monochromatic light sources are located on the border of the horseshoe-shaped figure on line 105, and non-monochromatic sources are located within the horseshoe shaped figure 106. Accordingly, any light source can be reduced to a set of u and v coordinates as shown. Specifically, lighting assembly 10 provides the monochromatic colour shown at A (with coordinates u' =.265, v'=.560) and the courtesy lights of the subject vehicle provides non-monochromatic colour as shown at B (with coordinates u'=.264, v'=.528).

Fig. 7 illustrates the preferred light transmission characteristic of the preferred colour of lens tube 14 which can be used to ensure that near incandescent quality light is reflected from running board step 18 when lens tube 14 used in association with the light spectrum of the green LEDs of LED array 12. It has been determined that when an appropriate amount and type of dye is mixed into the acrylic material of lens tube 14 to create the desired filter characteristics, lens tube 14 will absorb the appropriate wavelengths of light emitted by LED array 12 and the appropriate colour light (i.e. near incandescent quality light) will be reflected from the surface of running board step 18.

The specific dye used in the preferred embodiment of the present invention was obtained in cooperation with M.A. Hanna Color of Texas and categorized as masterbatch pigment number 10047174. It should be noted that while the rolloff slope is not as sharp as would be desired, the average cutoff wavelength is between 572 and 575 nanometres which

provides acceptable colour shifting of the light produced by LED array 12 for the present purposes.

Referring now to Figs. 6 and 7, when the light from the green LEDs of LED array 12 is passed through lens tube 14, wavelengths below the line C which represents a cutoff wavelength of approximately 572 nanometres (mostly "green" wavelengths) are significantly attenuated (Fig. 6A).

The resultant light emitted by lighting assembly 10, indicated by curve 102, has a peak wavelength of approximately 575 nanometres which is the closed quasi-monochromatic colour to the incandescent vehicle interior light. For comparison purposes the curve of a yellow (amber) LED is shown at 103. Since the preferred ROHM green LEDs of the present invention generate high illuminance, it is possible to shift the spectrum of the LED to yellow, by using lens tube 14 in this way, without reducing the illuminance of the resulting light below that which is generally produced by a conventional "yellow" (or amber) LED (curve 103 of Fig. 6A).

Referring again to Fig. 6B, the bell-shaped spectrum of the light emitted by lighting assembly 10, or curve 102, will be found on the CIE chromaticity chart at a different wavelength (Fig. 6A) than its peak wavelength might suggest. This is due to the fact that the response of the human eye varies with wavelength and that it is this colour response that is reflected in the CIE chromaticity chart of Fig. 6B. The difference between two colours with a distance d between their coordinates on the CIE chromaticity chart will be perceived to be as much as the difference between any other pair of colours with the same distance d between their coordinates. Accordingly, in order to find a monochromatic colour at A on line 105 that best matches a colour at B inside the horseshoe shaped region 106, it is necessary to ensure that the distance between the respective u'-v' coordinates is minimized.

In the present case, in order to find the monochromatic colour A on line 105 (i.e. of lighting assembly 10) that closely matches the

non-monochromatic colour B (i.e. of the courtesy lights of the subject vehicle) inside the horseshoe shaped region 106, the distance between the coordinates at A and B had to be minimized. Accordingly LED array 12 and lens tube 14 have been developed so that lighting assembly 10 provides a monochromatic colour (A) that is relatively close in perceived colour spectrum to that of the courtesy lights (B) of the subject vehicle.

Figs. 8 and 9 show an implementation of LED array 12 having 32 LED strings LS_1, LS_2 to LS_{32} such that LED string LS_1 comprises LEDs LED_2, LED_4, LED_6, and LED_8 connected in series as shown, LED string LS_2 comprises LEDs LED_1,LED_3, LED_5, and LED_7 connected in series and LED string LS_{32} comprises LEDs LED_{122}, LED_{124}, LED_{126} and LED_{128} connected in series. Also, adjoining LED strings LS_1 and LS_2, LS_3 and LS_4, to LS_{31} and LS_{32} are joined in parallel with eachother as shown and coupled in series with a current-limiting resistor R_1, R_2, to R_{16}, respectively. As shown, the strings are interleaved so that looking horizontally along LED array 12, no two successive LEDs are from the same string.

As previously discussed, power source 16 adapts the power provided by a standard 12 volt vehicle battery 15 for use by LED strings LS_1, LS_2 and LS_3. Resistors R_1, R_2, to R_{16} are preferably of a value of 82 ohms so that the current flowing through individual LED strings LS_1, LS_2 to LS_{32}, can be maintained at approximately 20 milliamps and the voltage across each individual LED at approximately 2.2 volts. As discussed above, printed circuit board 26 is preferably a flexible printed circuit board, such as the 2 micrometer polyamide board manufactured by Sheldahl, Inc., of Minnesota, U.S.A.

It should be noted that since the LEDs of LED strings LS_1, LS_2 to LS_{32} are physically interleaved on printed circuit board 23 (Fig. 9), therefore if one string of LED strings LS_1, LS_2 to LS_{32} fails (which will happen if one LED fails), the difference in the resulting overall lighting effect will not be perceived by a user. This is due in part to the preferred spacing of the LEDs of LED array 12 which creates an appreciable overlap of beam widths, as discussed above. Further, when one four LED string fails,

the remaining interleaved LED string will experience higher current (on the order of 1.7 times) and will effectively compensate in brightness for the failure of its matching LED string.

Fig. 10 is a block diagram of power circuit 16 which is adapted to receive the 12 volt input from vehicle battery 15 and which comprises a filtering and signal conditioning block 50, a voltage sensing block 52 and a microprocessor 54. While the above discussion has only addressed one LED array 12 and lens tube 14, it should be understood that power source 16 is designed to power two sets of LED arrays 12 and lens tubes 14 to provide a complete lighting assembly.

Filtering and signal conditioning block 50 filters the voltage and current spikes which might enter power circuit 16 through the wiring harness and those which are generated by power circuit 16 itself. Filtering and signal conditioning block 50 also steps down the voltage levels of the signal DC lines/inputs to voltages which can be input into microprocessor 54 using conventional methods.

Voltage sensing block 52 senses the voltage being output by battery 15 and provides an appropriate signal to microprocessor 54 to regulate the current. Specifically, if the voltage being provided by battery 15 is 12 volts, then when four LEDs are put in series (each consuming 2.2 volts) with a resistor, approximately 20 milliamps of current will pass through the LEDs of LED array 12. However, when the voltage being provided by battery 15 is at 16 volts, 40 milliamps of current will pass through the LEDs of LED array 12 and the LEDs may be endangered. Accordingly, voltage sensing block 52 provides an appropriate signal to microprocessor 54 which then limits the current to a safe level suitable for operation of LED array 12.

Microprocessor 54 of the present invention can be a conventional low-cost microprocessor such as PIC16C505 from Microchip Technology, although it should be understood that any type of logic circuit can be used. Storage of program instructions and other static data is provided by a read only memory (ROM) 56, while storage of dynamic data

is provided by a random access memory (RAM) 58. Both memory units 56 and 58 are controlled and accessed by microprocessor 54.

Microprocessor 54 implements logic instructions which determine whether power should be provided to LED array 12. As previously discussed, lighting assembly 10 is designed so that LED array 12 is only on when the courtesy lights are on, but is off when the car engine is on, as required under most state and provincial transportation regulations.

Also, microprocessor 54 receives the signal from voltage sensing block 52. According to the voltage supplied by battery 15, microprocessor 54 will regulate the power delivered to LED array 12 by generating a pulse width modulated signal at a desired frequency (on the order of 2 KHz) to control the operation of the MOSFET 62.

By turning the MOSFET 62 on and off at the above noted frequency and at the proper duty cycle, the desired current characteristics can be achieved for input into LED array 12. Even though LED array 12 will be pulsed on and off, the speed at which LED array 12 is turned on and off is sufficiently fast that the resulting visual effect cannot be reasonably perceived by a user. Also, it is possible for lighting assembly 10 to have variable brightness settings for LED array 12 by adapting power circuit 16 to provide higher current to LED array 12 and by installing a potentiometer within power circuit 16, as is conventionally known.

Figs. 11A, 11B, and 11C show three views of lens tube 14 at rest (Fig. 11A), and in the case of a mechanical shock or vibration (Figs. 11B and 11C). As shown, lens tube 14 is adapted to receive printed circuit board 23 within retaining channel 22. There is ample room within retaining channel 22 for printed circuit board 23 to have freedom of movement within retaining channel 22. Since printed circuit board 23 is a flexible printed circuit board, vibrational stress which is exerted on lighting assembly 10 when the vehicle it is installed in is in motion, can be attenuated by the vertical movement of printed circuit board 23 within retaining channel 22.

Specifically, printed circuit board 23 can move from a first

position when the vehicle is at rest (Fig. 11A) to a first deformed position (Fig. 11B) when vibrational stress has been exerted upwards to lighting assembly 10 and/or to a second deformed position (Fig. 11C) when vibrational stress has been applied downwards to lighting assembly 10. When the vehicle is at rest, LED array 12 is positioned above the retaining channel 22. Lens tube 14 is sized so that individual LEDs, LED_1, LED_{128} will not come in contact with the top surface of lens tube 14, even when printed circuit board 30 deforms under environmental stress (as in Fig. 11B). Thus, printed circuit board 23 and associated LED array 12 can be safely deformed in response to mechanical shocks and bumps and this arrangement will substantially reduce the amount of physical strain that is applied across the soldered joints of the LEDs and resistors which are mounted on printed circuit board 23.

In use, lighting assembly 10 is installed within cladding 17 of running board assembly 11 by sliding lens tube 14 within a channel defined by a plurality of support tabs 21. Normally a substantial portion of the lens tube 14 is exposed within slot opening 19 of cladding 17. Power circuit 16 may then be installed within vehicle so that lamp wires 7 connect power circuit 16 to the vehicle's battery 15. Once installed, LED array 12 will become operational when the courtesy lights are on and will turn off when the courtesy lights are off or when the engine is on. The user will observe that an even distribution of near incandescent quality light will be reflected up from the surface of running board step 18 and that the region of the ground proximate to running board step 18 will also be illuminated.

Lighting assembly 10 may alternatively be implemented as a plurality of LED arrays 12 (i.e. more than two) in a case where it is aesthetically desirable to split the LED array and/or to only illuminate certain areas of running board step 18. Further, illumination level could be reduced along certain areas of running board step 18 by spacing the LEDs of LED array 12 unevenly as desired. Finally, the logic module of microprocessor 54 could be adapted to illuminate only the drivers step pad

when only the drivers door is unlocked to serve as a further indicator light.

Thus, lighting assembly 10 provides an evenly distributed light along the surface of a running board step such that near incandescent quality light is reflected from the running board step. Since lighting assembly 10 uses LEDs it is designed to withstand substantial environmental and operational stresses associated with roadside application. Also, since lighting assembly 10 uses LEDs, it can operate for a long period of time without replacement and requires minimal maintenance. Finally lighting assembly 10 contains a minimal number of parts and can be manufactured easily and inexpensively.

As will be apparent to persons skilled in the art, various modifications and adaptations of the structure described above are possible without departure from the present invention, the scope of which is defined in the appended claims.

WE CLAIM:

1. A running board lighting assembly for the illumination of the surface of a running board step of a vehicle, said running board lighting device comprising:
   - (a) a plurality of LEDs spaced apart from each other and extending horizontally above the surface of the running board step;
   - (b) a light transmitting member encasing the LEDs; and
   - (c) a power circuit for supplying electrical power to the LEDs.

2. The running board lighting assembly of claim 1 wherein said LEDs are spaced apart horizontally from each other by substantially equal distances.

3. The running board lighting assembly of claim 1 wherein said LEDs and said light transmitting member are installed within a cladding member of the vehicle.

4. The running board lighting assembly of claim 1 wherein each light emitting diode of said LEDs is a green light emitting diode, which also emits light at longer wavelengths.

5. The running board lighting assembly of claim 1 wherein said LEDs are electrically coupled to a printed circuit board.

6. The running board lighting assembly of claim 5 wherein said light transmitting member comprises a watertight enclosure, such that said LEDs and said printed circuit board are housed in the watertight enclosure.

7. The running board lighting assembly of claim 1 wherein the light transmitting member includes a horizontally extending diffraction lens.

8. The running board lighting assembly of claim 7 wherein said light transmitting member has a series of horizontally oriented ribs formed on its inside surface such that the light emitted by said LEDs is diffracted into a set of uniform laterally extending bands of light on the running board step.

9. The running board lighting assembly of claim 7 wherein said light transmitting member has a curved outside surface.

10. The running board lighting assembly of claim 7 wherein said light transmitting member is extruded from plastic.

11. The running board lighting assembly of claim 4 wherein said light transmitting member contains dye such that the light emitted by said green LEDs is appropriately spectrum altered such that near incandescent quality light is reflected from the running board step.

12. The running board lighting assembly of claim 1 wherein said power supply comprises a power circuit which is electrically connected to the battery of the vehicle, said power circuit being adapted to regulate the power provided by said battery to power said LEDs.

13. The running board lighting assembly of claim 1 wherein said power circuit includes a microprocessor which controls the electrical power to said LEDs in accordance with the operation of the courtesy lights of the vehicle and the operation of the vehicle's engine.

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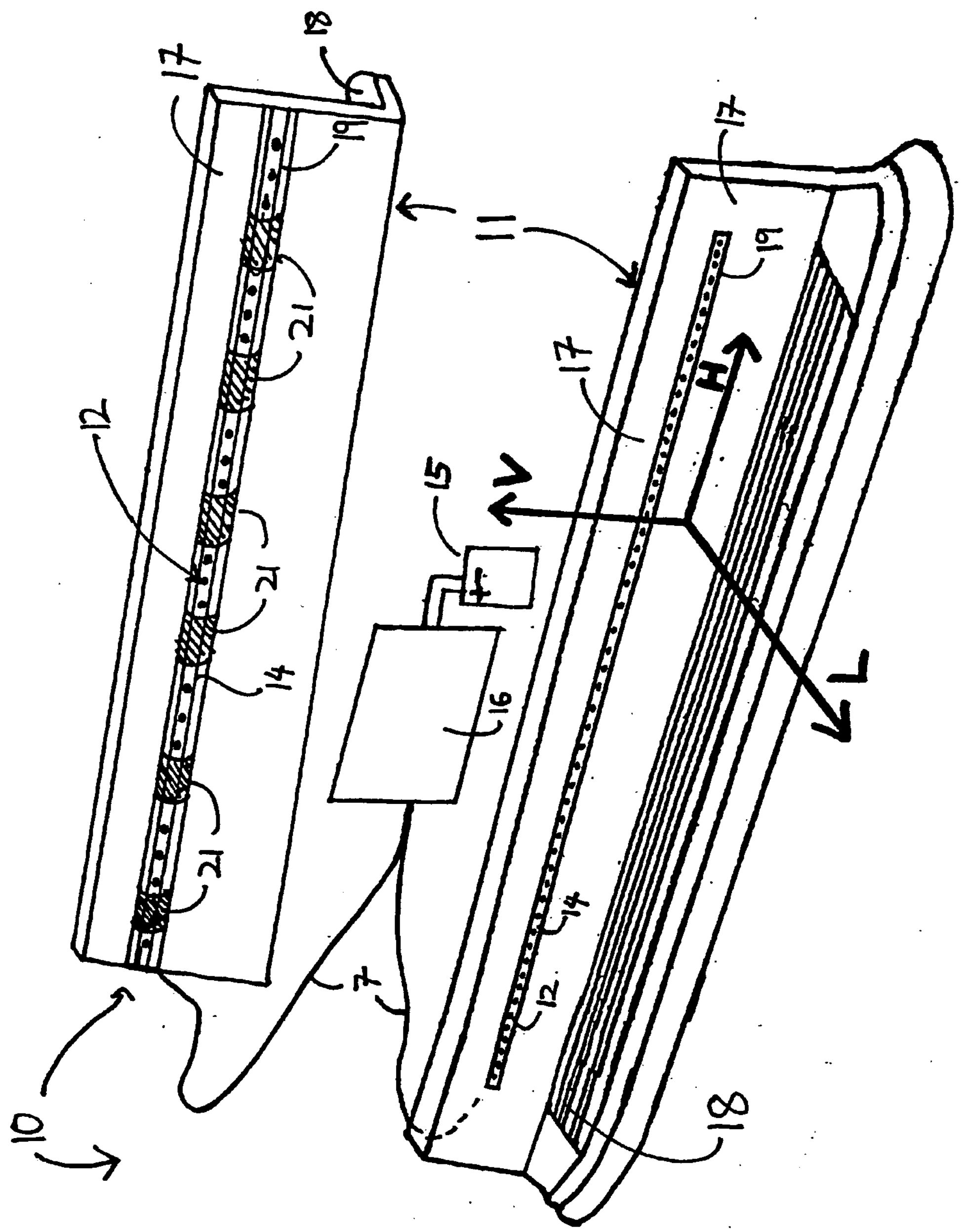


FIG. 1

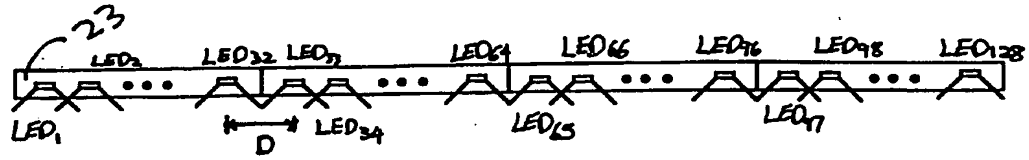


FIG. 2A

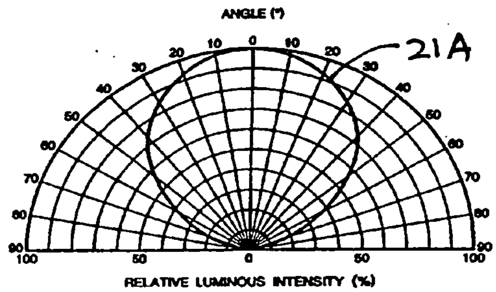
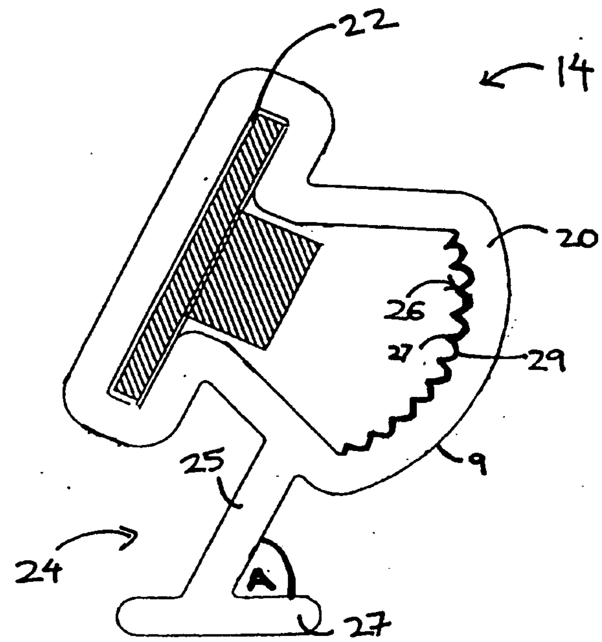


FIG. 2B

FIG. 3



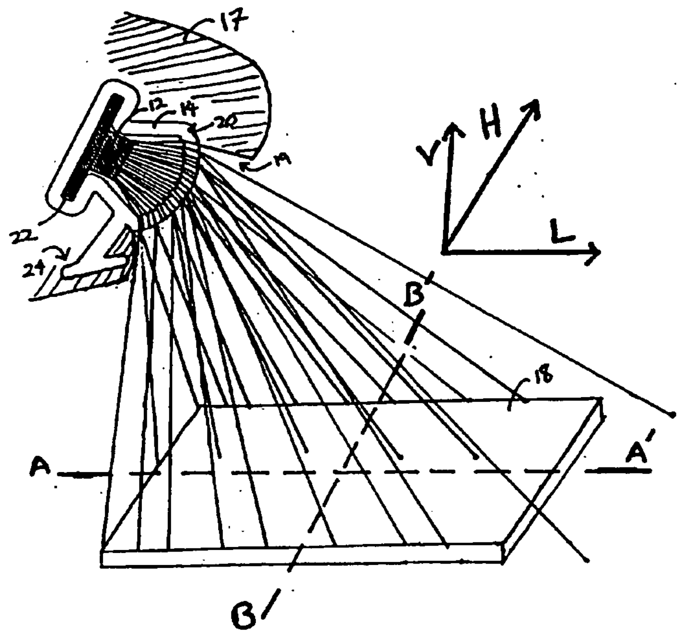

17
12
14
20
19
22
24
V
H
L
B'
18
A
A'
B

FIG. 4A

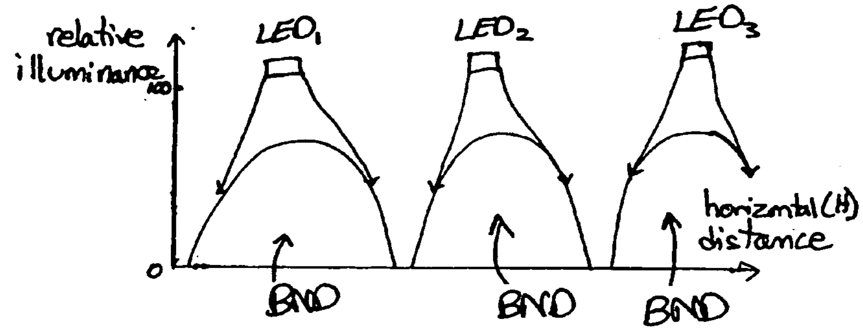

relative
illuminance
100
LED1
LED2
LED3
horizontal (H)
distance
0
BND
BND
BND

FIG. 4C

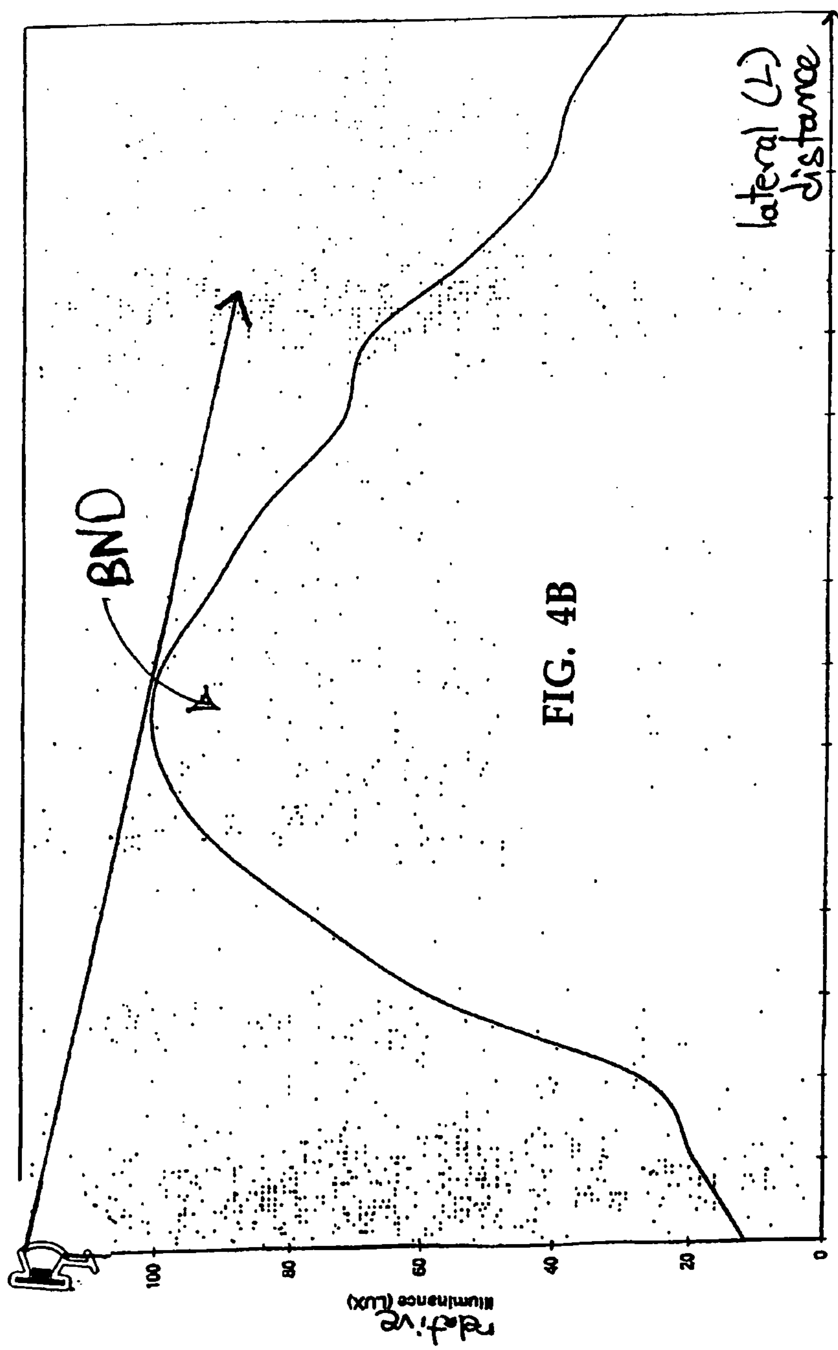

BND
lateral (L) distance
relative Illuminance (LUX)
Distance (cm)
0
20
40
60
80
100
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

FIG. 4B

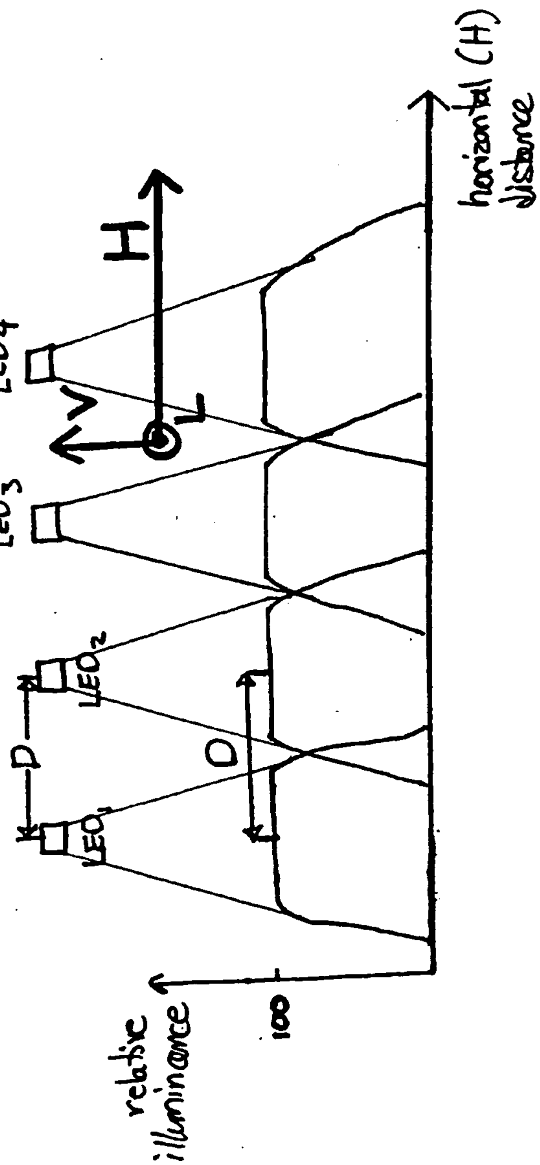
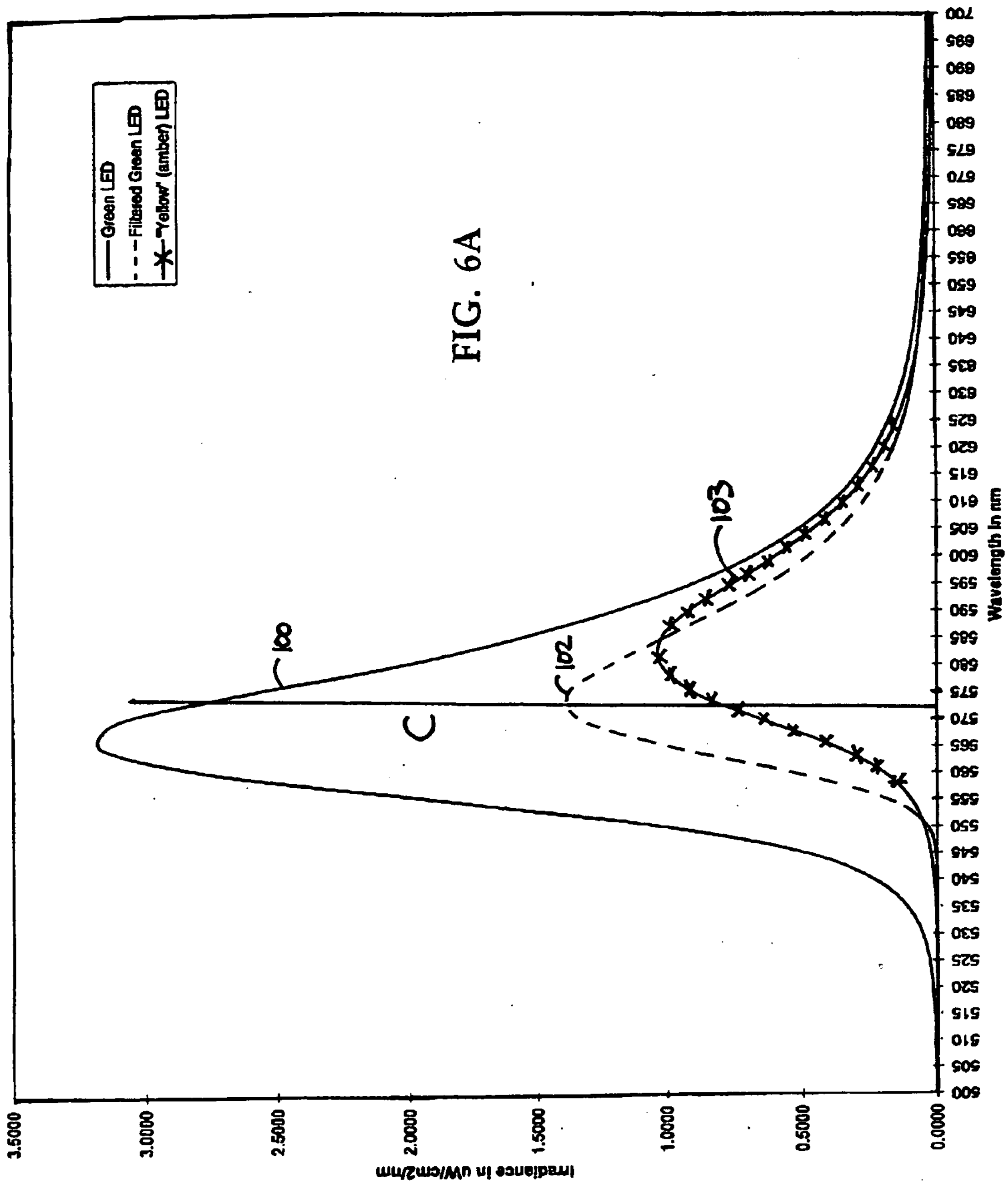

relative illuminance
100
LED1
LED2
LED3
LED4
D
D
V
L
H
horizontal (H) distance

FIG. 5



Green LED
Filtered Green LED
"Yellow" (amber) LED
Irradiance in uW/cm2/nm
Wavelength in nm
100
102
103
C

FIG. 6A

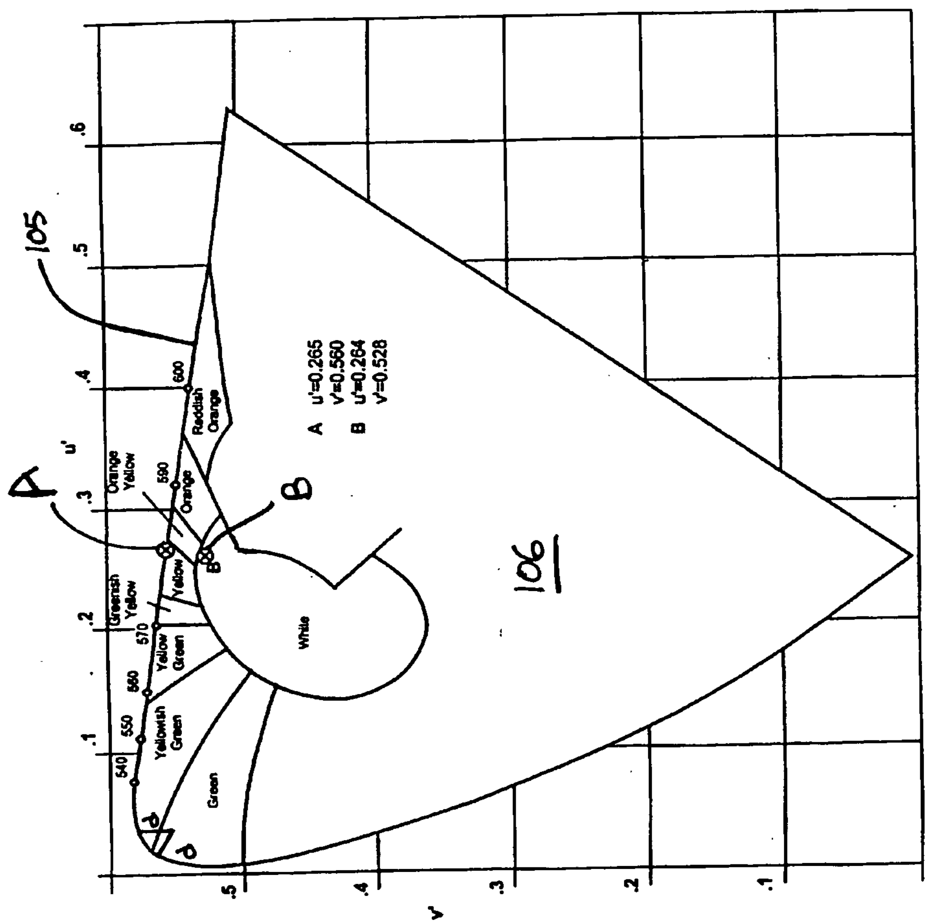

105
A
B
u'
v'
.1
.2
.3
.4
.5
.6
540
550
560
570
590
600
Green
Yellowish Green
Yellow Green
Greenish Yellow
Yellow
Orange Yellow
Orange
Reddish Orange
White
A u'=0.265
v'=0.560
B u'=0.264
v'=0.528
106

FIG. 6B

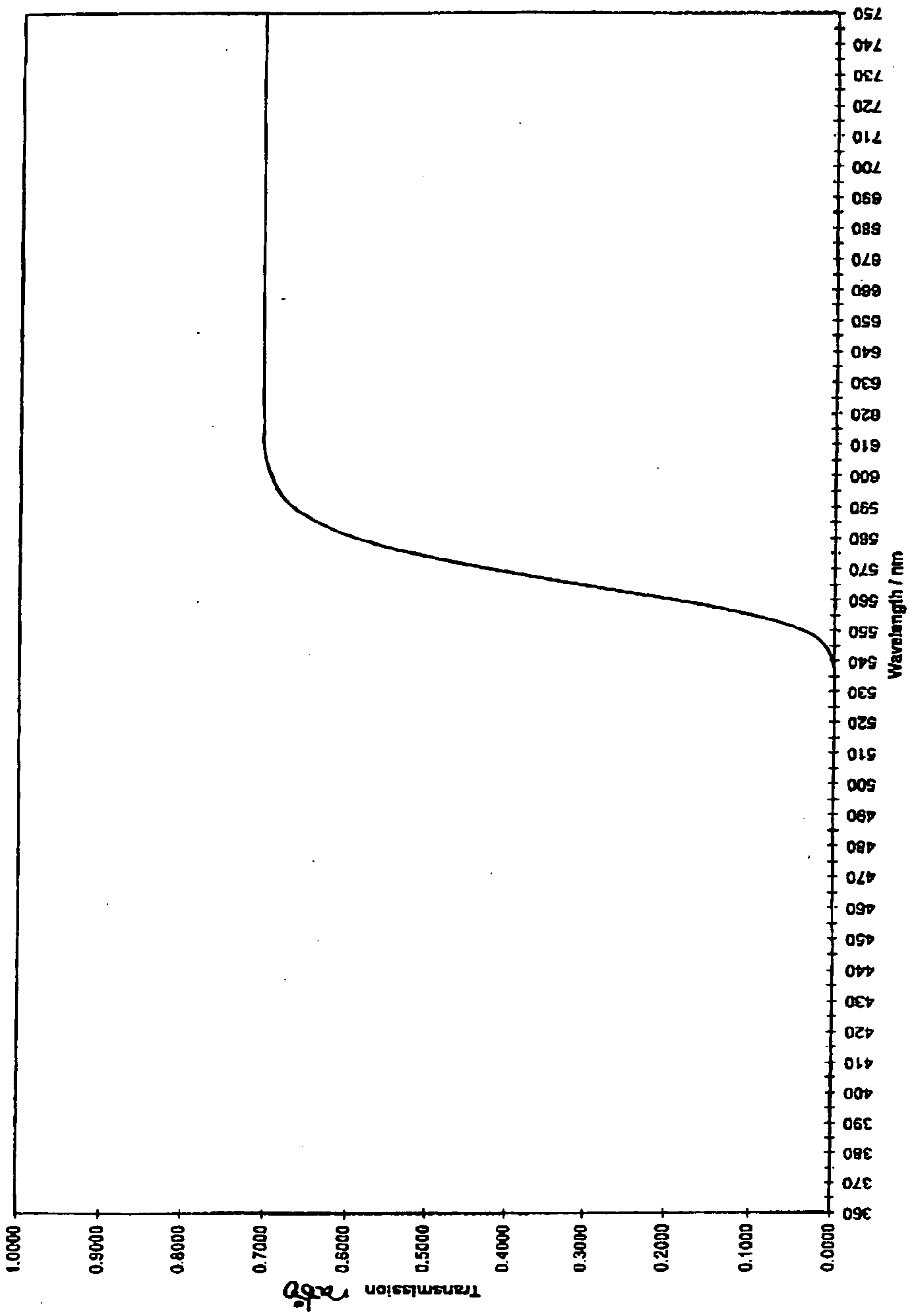

Transmission ratio
1.0000
0.9000
0.8000
0.7000
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0.0000
Wavelength / nm
360
370
380
390
400
410
420
430
440
450
460
470
480
490
500
510
520
530
540
550
560
570
580
590
600
610
620
630
640
650
660
670
680
690
700
710
720
730
740
750

FIG. 7

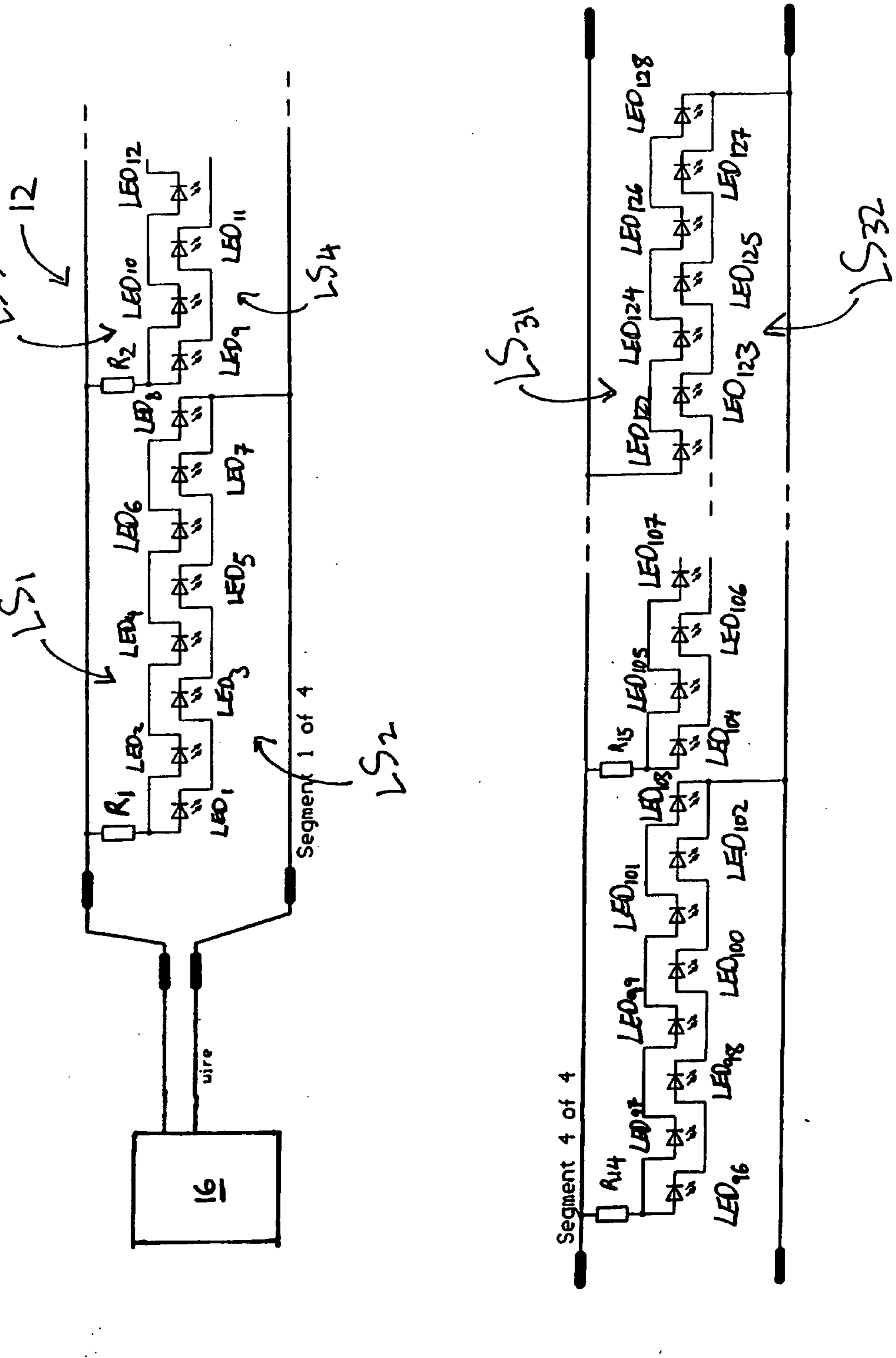

12
LS3
LS4
LS1
LS2
R1
R2
Segment 1 of 4
wire
16
LS31
LS32
R14
R15
Segment 4 of 4

FIG. 8

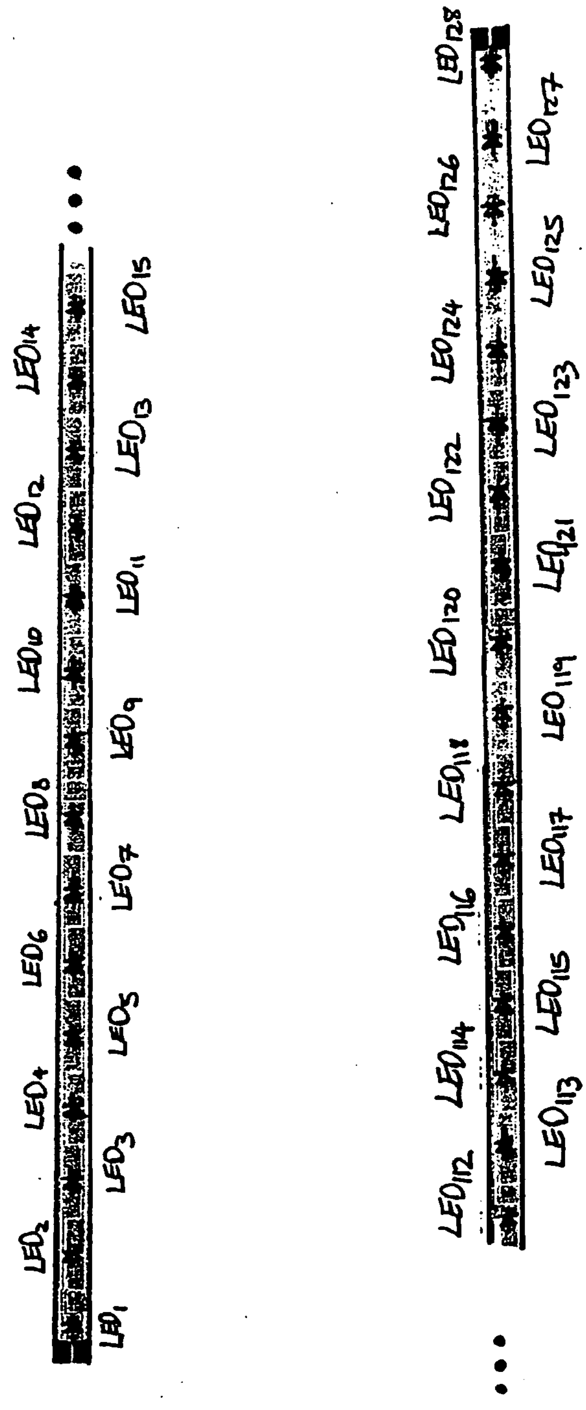

LED1
LED2
LED3
LED4
LED5
LED6
LED7
LED8
LED9
LED10
LED11
LED12
LED13
LED14
LED15
LED112
LED113
LED114
LED115
LED116
LED117
LED118
LED119
LED120
LED121
LED122
LED123
LED124
LED125
LED126
LED127
LED128

FIG. 9

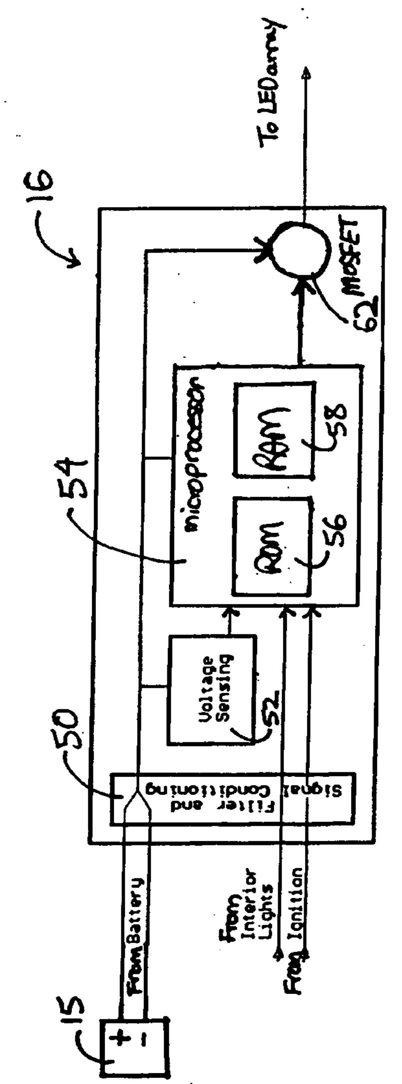

16
To LED array
MOSFET
62
microprocessor
54
ROM
56
RAM
58
Voltage Sensing
52
50
Filter and Signal Conditioning
From Battery
From Interior Lights
From Ignition
15
+
-

FIG. 10

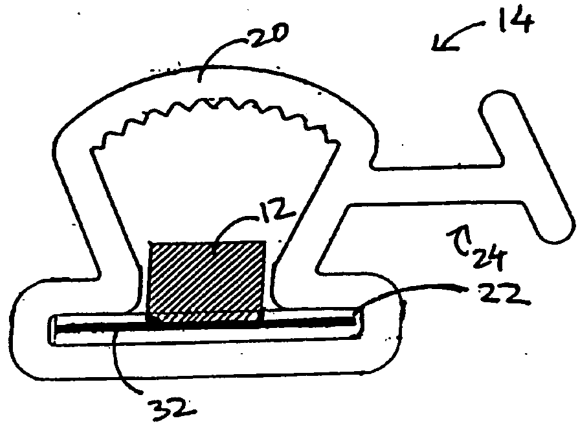


FIG. 11A

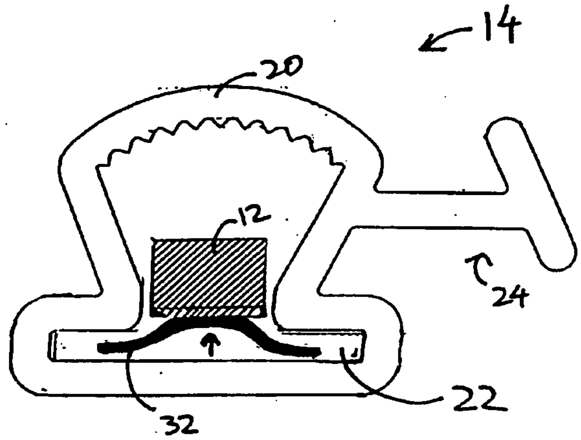


FIG. 11B

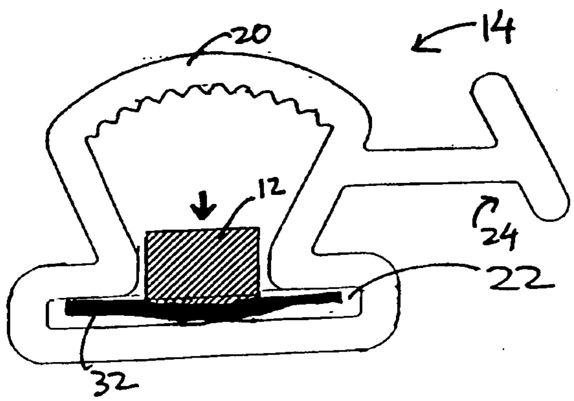


FIG. 11C

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